Prediction of the Ash Split in a CFBC Boiler to Improve the Energy Efficiency Using Fuel and Sorbent Properties

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Background and Analysis of the Problem

In Pennsylvania alone,14 CFB plants are operating and burning waste fuels. These materials can range from 20 to 70 wt% in ash, and sulfur can be in excess of 4 wt%. Ash removal systems are expensive components in a CFB plant.

Predicting the ash split in a fluidized bed boiler has been elusive even after two decades of development and operation. Bottom ash is removed from a CFB boiler at the bed temperature (800+ C), and must be cooled prior to its handling by pneumatic or drag chain conveyors. The sensible energy in this ash stream can be substantial. In the case of CFB boilers fired with high ash content coal products, the heat that must be removed from this ash stream can be over 1% of the thermal input to the system. Optimizing the state-of-the-art for recovering this energy can ultimately lead to increased efficiencies for CFB boiler systems. This could lead to the following:

- Improved competitiveness of CFB boiler technologies in worldwide markets.
- Reductions in greenhouse gas emissions per unit power output.
- Reduced financial and technical risks associated with CFB power projects.

Objective

- Develop means of predicting the generation rate of bottom ash (under steady bed level conditions), based on properties that can be measured in a laboratory.
  - Particle size
  - Gravity separation
  - Attrition properties

Prediction of Generation of Bed Ash Requires

- Quantification of size classification of bed solids into the two ash streams
- Qualification of the transformations undergone by the feed solids prior to removal with the ash streams
- Attrition coefficients
  - Based on ash content distribution of fuel (float sink analysis)
  - Based on sorbent petrographic characteristics

Evaluation of the Size Classification to the Two Ash Streams

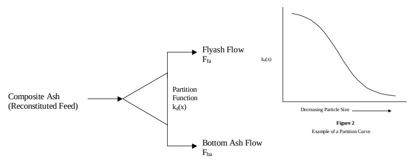


Figure 2
Example of a Partition Curve

$$F_{ba} = \sum_{x=1}^{nx} k_d(x) M_{ca,x} F_{ca}$$

$$F_{ba} + F_{fa} = F_{ca}$$

Attrition Coefficient

The attrition coefficient for species i can be described as follows:

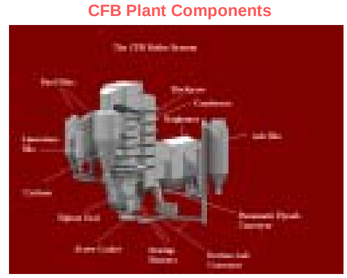
$$K_{i,a} = 1 - \left(\frac{M_{i,ba}}{M_{i,kd}}\right)$$

The mass fraction of particles of species i that reports to the bottom ash stream

The mass fraction of particles of species i initially coarse enough to report to the bottom ash stream

$$M_{i,kd} = \sum_{x=1}^{nx} k_d(x) M_{is,x}$$

CFB Plant Components



Methodology

- **Data Acquisition and Solids Samples**
  - Bed Pressure
  - PA Flow
  - SA Flow
  - Fuel Flow
  - Sorbent Flow
  - Bed Temperature
  - Main Steam Flow
- **Physical and Chemical Analyses of Solids**
- **Material Balances and reconstitutions of ash flows from the boiler**
- **Development of boiler partition function**
- **Development of attrition coefficients**

Bottom Ash

Flyash

First Plant Tested

CFB Power Plant net Export Capacity, MW	100
Fuel	Coal Waste
Limestone	Micritic
Bottom Ash System	Screw Coolers
Flyash System	Baghouse

Sorbent attrition may be evaluated through a CaO material balance around the combustor:

$$M_{s,kd} = \sum_{x=1}^{nx} k_d(x) M_{s,x} \qquad K_{s,a} = 1 - \left(\frac{F_{Ca,ba} - F_{Ca,ba,f}}{F_s M_{s,kd} Ca_s}\right)$$

The contribution of the sorbent to the bottom ash flow rate may be expressed by:

$$F_{ba,s} = F_s (1 - L_s)(1 + S) \sum_{x=1}^{nx} k_d(x) M_{s,x} (1 - K_{s,a})$$

$$F_{ba,f} = F_f \sum_{x=1}^{nx} \sum_{y=1}^{\infty} k_d(x) [1 - K_{f,a}(y)] M_{f,x,y} A_{x,y}$$

A total predicted bottom ash flow rate is:

$$F'_{ba} = F_{ba,s} + F_{ba,f}$$